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CASE STUDY PAPER ON FIELD INSPECTION OF REBARS & CAUSE FOR CORROSION BY IS/ACI/ASTM NORMS

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ABSTRACT

In my 15 years of experience careers many people discuss on rust of reinforcing bars is a common question asked by both design and construction professionals, and fielded by the regional and many contractors companies. The questions usually focus on bond and development length concerns, and whether the corrosion mechanism will continue once the reinforcing bars are embedded in the concrete. In addition to rust, other common concerns are the presence of mill scale or other surface contaminants on the bars before the concrete is placed. Typical surface contaminants usually include in the form of oils, fuel spills, dirt sticking to wet bars, etc. To clear the overall doubts for these problems, I have prepared this detailed Technical case study papers concepts by considering all angle points for detailed and Technical clarification by IS/ACI/ASTM Codes and specifications.

In reinforced concrete construction, bond between the concrete and reinforcing steel plays a critical role. Bond, either through adhesion/cohesion or mechanical interlock, provides for the transfer of stresses from concrete to steel, producing composite action with materials that have markedly different mechanical properties. There can be contaminants on the reinforcing bar surface, which are commonly assumed to impede the bond. If the bond becomes compromised, the ultimate behaviour and serviceability characteristics of reinforced concrete structure can be altered. Rust on reinforcing steel is not necessarily a bad condition. Present specification requirements contain very conservative language, essentially mandating cleaning of the reinforcing steel; this is not fully supported by the research evidence. In spite of these known facts, most engineers and inspectors alike take a conservative approach by requiring the removal of such materials from reinforcing bar. Rust can enhance the bond characteristics of the bar to the surrounding concrete. Obviously, loose material should be removed from the bar. Tightly adhering rust or mill scale is permissible, and will not be detrimental to bond.

Generally accepted construction quality control measures require the removal of deleterious contaminants due to the concern for a reduction in bond capacity. Figure 1 illustrates a common example of rust on the reinforcing bars in a fabricated column cage. The corresponding construction activity required to clean the reinforcing bar has significant time and expense implications. This technical note explores, in-depth, a common issue of rust and mill scale on steel reinforcing bars at the time of concrete placement, and how much rust is tolerable before it becomes detrimental to the proper performance of the bar when embedded in concrete.

KEYWORDS: Inspection, Corrosion, Rusting, Preventive Measures, Epoxy Coating, Compliance, Tolerance, Limits Specifications, Rebar's, Protective Coatings, splices, Welding's, Tying, Anti-corrosive, Treatments, Corrosion, Surface Contaminants, Mill Scale, Bond Stress, Development, Bond Strength, Slip & Pull-out test

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INTRODUCTION

In a perfect world, quality control or inspection to assure compliance with project drawings, project specifications, material standards, and building codes would not be necessary since the project drawings and project specifications

would be complete without errors or omissions, the materials would be manufactured exactly to the material standards, and the field workmanship would be precise. However, in the real world, quality control programs are recommended with inspection usually mandated to ensure compliance with a regulatory agency's policies. Why is this necessary?

Project drawings are not always complete due to an owner's desire for a rapid start and completion of a project. Materials may not meet the standards due to variations in the raw material or the manufacturing process. Workmanship is not always accurate due to improper training, inadequate experience, or careless supervision. Thus, there is recognition by owners, contractors, architects/engineers, and regulating agencies that programs for quality control and inspection are necessary to ensure compliance with the contract documents and the building code applicable to the project under construction.

The benefits of a quality control program and mandated inspection are mainly monetary, but they also ensure structural safety and compliance with architectural requirements. The owners, private and governmental, benefit with lower total costs, on time construction schedules, and quicker occupancy. The architect/engineer benefits in the knowledge that the structure will conform to the design intent. The contractor, his subcontractors and suppliers, and all their employees will benefit in a similar manner. The public, as the ultimate consumer and user of the structure, benefits in the knowledge that the structure has been built according to the contract documents.

INSPECTOR QUALIFICATIONS

Inspectors are individuals qualified to perform the inspection tasks. They should have education, training, experience and have the ability to read and understand project specifications, material standards, project drawings, and building code requirements. In the event of field problems, they must work with the contractor and make decisions on improvised details if the architect/engineer is unavailable to provide direction. An inspector must project confidence in his decisions. He should be meticulous, correct, fair, and firm, along with the ability to compromise when faced with a dispute regarding a conflict in the contract documents or actual field conditions, or both.

INSPECTION GOALS

The goal of any inspection or quality control program is to ensure whether the intent of the contract documents is met and that the requirements of the building codes are followed. Inspection and testing by themselves do not add quality to the product or the material being inspected, only confirm whether or not what is being inspected meets the criteria established by the project drawings, project specifications, and building code.

Quality during the construction process is achieved almost entirely by the contractor's quality assurance program, which depends on and involves all workers and field supervisors. The contractor's inspectors are his employees and are separate from the inspectors mandated by the owner or local building department. The quality control inspection by the contractor helps to assure that the finished construction meets the owner's requirements, while similar programs by the material producers and suppliers assure that the products and materials being supplied will meet the specific requirements of the material standards. The final in-place acceptance inspection is a formalized procedure that provides the owner and regulatory agency with an acceptable degree of assurance that the contractor has satisfied his obligations as described in the contract documents and by the building code. To accomplish this end, the inspector must familiarize himself with the project specifications and project drawings, have reasonable knowledge of the building code requirements, have access to material standards and reference codes, and have available industry manuals and reports (See References).

At the start of a construction project, whether small, medium or large, it is recommended that the inspector establish an inspection program for the reinforcing bars. The program can be established at a preconstruction conference with the general contractor's superintendent, the supplier's representative, the ironworker foreman, and other interested parties such as the architect/engineer or the architect/engineer's inspector. This meeting should establish a checklist procedure and minimum requirements for inspection acceptance.

INSPECTION CHEKLISTS

The checklist for the inspection of reinforcing bars should include, but not be limited to the following:

Construction Schedule: A construction schedule from the general contractor is important and necessary, so that, the inspector can follow the reinforcing bar placing crew and carry out his inspection in the place of reinforcing bars prior to the scheduled placing and finishing of the concrete.

Certified Mill Test and/or Bar Coating (Certification) Reports: These reports may accompany the shipments of material to the job-site, and thus should be available to the inspector. In the event, the reports are sent to the contractor's office rather than to the job-site, arrangements should be made to make them available to the inspector.

Independent Testing Laboratory Reports: The reports on samples taken either at the reinforcing bar fabricator's shop or from material shipped to the jobsite, offer supplemental verification of the producer's mill test report.

Approved Placing Drawings: The latest approved placing drawings should be available for review and study by field placing personnel and the inspector inspects at least one day prior to the actual placing of the reinforcing bars.

Material Shipment: A schedule of anticipated delivery dates should be provided and updated as necessary so that the inspector can schedule his in place inspection.

Potential Problems: A discussion between all parties is desirable to identify difficult-to-place reinforcement details, lack of specific details or information on the contract documents, possible structural drawing discrepancies, detailing or placing errors, and verification and acceptability of implemented field changes.

Tolerances: A discussion with all parties is necessary regarding which tolerances are critical, the method of measurement, and the basis for either rejection or acceptance.

Periodic Meetings: It is recommended that regularly scheduled meetings to be held in order to discuss the previous inspection reports, any problems that were encountered, solutions to the problems, and the schedule of work for the next period.

MATERIAL INSPECTION

In-place inspection of reinforcing bars starts with the mill test report, which in some cases it is supplemented by a report from an independent testing laboratory. Both reports should provide data as to grade of steel, tensile properties (yield strength, ultimate tensile strength, and percentage of elongation), bend tests, chemical composition and carbon equivalent (CE) in the event the reinforcing bars are to be welded, and the spacing and height of deformations. The reported data should meet the requirements of the applicable ASTM standard. A visual examination of the mill markings on a bar will identify the producing mill, the bar size, the type of steel, and the grade of steel.

INSPECTION OF IN-PLACE REINFORCING BARS

Inspection of the reinforcing bars installed in the forms is done by visual examination of the layout pattern, and by measurement of spacing and counting of bars. The bar diameter and the bar shape, if bent, can be visually checked. Bar lengths, bar spacing's, embedment's, and bearings on walls or beams are normally checked by measurement. In a slab, the total number of pieces can be counted with the spacing of the slab bars verified by measurement, all checked against the approved placing drawings in conjunction with the structural drawings. Similarly, beam longitudinal bars, column vertical bars, and stirrup and tie spacing's are checked visually and by measurement, as required.

BARS SUPPORTS

At the same time the beam and slab reinforcing bars are being inspected, the heights of bar supports should be measured to verify that the concrete cover and clearances will be as specified. It is extremely important that the bar supports for slab or mat top to bars be checked not only for height but also for stability, since they can easily displaced during the placement of concrete. In fact, the entire mat and cages of reinforcing bars should be checked for stability for the same reason. If the project specifications require corrosion-protection measures, the class of protection of the bar supports furnished should be verified.

TYING REQUIREMENTS

Reinforcing bars are tied together to form a rigid mat for footings, walls, and slabs. A cage is formed when beam or column longitudinal bars are wire tied to the stirrups and ties, respectively. Ironworkers are usually instructed to tie a minimum number of intersections. Unless the project specifications are very specific about the number of intersections to be tied, the inspector should accept the work unless it is apparent that the mats or cages of reinforcing bars will be displaced from their inspected position during the casting, screeding, and finishing of the concrete. The placer is responsible for tying reinforcing bars in such a manner that the bars will not be displaced. The inspector should only verify and agree that this condition has been achieved. Only coated tie wire should be used to tie coated reinforcing bars.

CRSI's book, Placing Reinforcing Bars, the authoritative publication on placing practices, states in its Chapter 10 under General Principles of Tying Reinforcing Bars:

It is not necessary to tie reinforcing bars at every intersection. Tying adds nothing to the strength of the finished structure. **The tying of rebar's Technical details describe in separate section C in this Paper.**

SPLICES

The inspector should pay particular attention to the location and length of lap splices. Lap splices should be specified as to the length and location on the contract documents, as well as shown on the approved placing drawings. In the event, the mechanical splices are required in lieu of lap splices, the placing foreman and/or the mechanical splice supplier should provide literature describing the recommended installation and inspection procedures.

SURFACE CONDITIONS OF BARS

A light surface coating of rust on reinforcing bars should not be a cause for rejection by the inspector. The ASTM standards and the ***ACI 318 Building Code*** describe how to inspect and evaluate rusted reinforcing bars. However, dirt, grease, or other deleterious materials on the reinforcing bars, i.e., materials that can affect bond, must be removed prior to

concrete placement. Tests have indicated that water soluble cutting oils, those used when threading ends of bars for attaching to mechanical splices, do not significantly affect bond.

DAMAGE TO BAR COATING

If epoxy-coated or zinc-coated (galvanized) reinforcing bars are specified for corrosion protection, the project specifications should be studied to determine the criteria for acceptance or rejection in the event, there is damage to the coating. Any corrective actions should follow recommended repair procedures and should be completed prior to acceptance by the inspector.

TOLERANCES

No structure is built exactly level, plumb, straight, and true to line. Tolerances are the means used to establish permissible variations in dimensions and locations. Thus, the architect/engineer, contractor, and inspector have parameters within which the work can be performed and inspected. Tolerances should neither be overly restrictive nor lenient. The contract documents should specify the standard tolerances to be followed, usually by reference to the ACI 117 Specification. Judgment on the part of the inspector will establish a range of acceptability. Incompatible tolerances should be referred to the architect/engineer for resolution.

FABRICATING TOLERANCES

Fabricating tolerances for reinforcing bars are established in the ACI 117 Specification, the ACI Detailing Manual, and the CRSI Manual of Standard Practice. Shearing length tolerance for straight bars is ±1 inch. The out-to-out dimension of bars with hooks or bends at one end or at both ends is ±1 inch. Stirrups, hoops, and ties that fit into a beam or column form, for bar sizes #10, #13, and #16, with a gross length of 12'-0" or less, have a tolerance of ± 1/2 inch. When a gross length exceeds 12'-0", the tolerance is increased to ± 1 inch.

PLACING TOLERANCES

Placing tolerances recognize the imprecise nature of the placing operation and allow deviation criteria. The ***ACI 117 Specification*** indicates tolerances on clear distance to side forms and resulting concrete surfaces and on the clear distance to form concrete soffits in the direction of the tolerance. These tolerances are:

Table 1: Tolerance Limits

Member Size	Tolerance
≤ 4 in.	± ¼ in.
> 4 in. and ≤ 12 in.	± ⅜ in.
> 12 in.	± ½ in.

The ACI 117 tolerances for concrete cover measured at right angles to the concrete surface in the direction of the tolerances are:

Member Size	Tolerance
≤ 12 in.	– ⅜ in.
> 12 in.	– ½ in.

Reduction in concrete cover is permitted by ***ACI 117.*** Generally, the reduction should not exceed one third of the specified cover. For formed soffits, the reduction in cover is limited to 1/4 inch.

The uniform spacing or centre-to-centre distance between reinforcing bars in slabs and walls have a tolerance of 3 inches from a specified location. The tolerance in the longitudinal location of bends and ends of bars, in general, is ±2 inches, but at a discontinuous end of a structural member the tolerance is reduced to ±1 inch. The length of lap splices has a tolerance of −1 inch. Obviously, a longer splice length would be considered safer; hence there is no plus tolerance. Finally, the tolerance for embedded length is −1 inch for bar sizes #10 to #36 and −2 inches for bar sizes #43 and #57. In terms of percentages, these tolerances may be considered liberal, and normally are easily met. A longer splice length would be considered safer; hence there is no plus tolerance.

The tolerances for deviations from cross-sectional dimensions, except slabs, are:

Table 2

Specified Dimension	Tolerance
≤ 12 in.	+ ⅜ in., – ¼ in.
> 12 in. and ≤ 36 in.	+ ½ in., – ⅜ in.
> 36 in.,	+ 1 in., – ¾ in.

The tolerance for the thickness of suspended slab is −¼ inches.

A potential problem occurs if the stirrups or ties are fabricated to the plus tolerance of ½ inch when the forms are made to the minus tolerance of 3/8 inch. This condition has the effects of reducing the clearance to 7/16 inch on each side of the stirrups or tie. The inspector must determine whether or not this encroachment on concrete cover is critical. As previously stated, the ACI 117 specification permits a reduction in concrete cover or 3/8 inch when the member size is 12 inches in the direction of tolerance. This type of problems should be resolved with the assistance of the architect/engineer.

The tolerance for beam and column forms is +1/2 inch and −3/8 inch to form dimensions larger than 12 inches but not over 36 inches. A potential problem occurs if the stirrups or ties are fabricated to the plus tolerance of 1/2 inch when the forms are made to the minus tolerance of 3/8 inch. This condition has the effect of reducing the clearance to 7/16 inch on each side of the stirrup or tie. The inspector must determine whether or not this encroachment on concrete cover is critical. As previously stated, the ***ACI 117 Specification*** permits a reduction in concrete cover of 3/8 inch when the member size is 12 inches or less, and 1/2 inch if the member is over 12 inches in the direction of tolerance. This type of problem should be resolved with the assistance of the architect/engineer.

Another example of encroachment on concrete cover is a formed footing; the form tolerances is +2 inches and −1/2 inch, while the tolerance on the reinforcing bars, either straight or bent, is ±1 inch. Again, if the forms are 'minus' and the reinforcing bars are 'plus', the concrete cover at each end of the bars is reduced from 3 inches to $2^{1/4}$ inches. This condition would be acceptable since the allowed reduction in concrete cover is 1 inch for sizes of structural members in excess of 2 feet.

In another example, the length of a beam which is discontinuous at each end may create a problem if the formwork is 'minus'; at the same time, the reinforcing bars are 'plus'. Each trader, carpenter and ironworker, can claim that their work is within tolerance, thus squarely putting the problem into the inspector's lap to make a decision. The inspector must determine whether the encroachment on concrete cover is detrimental to the safety and service life of the structure, or is within the allowable limits of reduction in concrete cover.

Inspection of reinforcing bars placement in walls and slabs is usually straight-forward and normally no misplacement will be found. Small openings, pipe sleeves, electrical outlets, and similar items may interfere with the specified location of the reinforcing bars, but the ironworker usually will shift the reinforcement to one side or the other to avoid the obstruction***. The ACI 117 Specification*** allows a maximum deviation from the specified location of 3 inches. This deviation normally is sufficient, provided that the total number of bars in a wall or slab panel is not reduced. No cutting of reinforcing bars should be done to clear obstructions without any approval by the architect/engineer.

The spacing ***ACI 117*** spacing tolerance for stirrups measured along a line parallel to the stirrups spacing is the lesser of ±3 inch, ±1 inch per ft. of beam depth. For column ties, the requirements are the same except the least column width is the key dimension instead of beam depth. Thus, stirrup or tie placement in an 18 inch square beam or column could vary from the specified location by 1½ inches.

IN-SITU BENDING AND RE-BENDING

The practice of bending and re-bending installed reinforcing bars is often questioned. Many conditions and situations at the job-site require such bending and re-bending. As an example, the horizontal leg of bend reinforcing bars (fabricated) projecting from a wall to become the top bars of a beam may have been improperly placed too low or too high, well in excess of concrete cover and placing tolerances. These bars will require 'straightening' and then 're-bending' to the proper position. The inspector, after consultation with the architect/engineer, should approve the procedure used to accomplish the task. Section R7.3.2 in the Commentary of the ***ACI 318 Building Code*** presents guidelines for straightening and re-bending embedded reinforcing bars. Section 3 in the ***ACI 301 Specifications*** includes provisions for field bending or straightening of reinforcing bars.

(Note: *This subject is not related to the fabrication of reinforcing bars. Fabrication of reinforcing bars is the cutting-to-length of straight bars, and cutting-to-length and bending to shape of bent bars. The issue here is concerned with bending and straightening or re-bending of reinforcing bars that are partially embedded in hardened concrete*.)

In some instances, the use of planned pre-bent dowels is requested by the contractor. The architect/engineer should review the request and notify the inspector. Similarly, straight dowels may be planned to be field bent into place, such as an outside face wall where vertical bars will be bent horizontally to become the slab end top bars. This procedure is intended to facilitate slab formwork erection. Again, the architect/engineer should review the procedure and notify the inspector. The inspector should discuss the bending procedure with the placing foreman to ensure that the bends conform to the ***ACI 315 Standard.*** Where large diameter bars are involved, some amount of heating may be recommended by the architect/engineer to avoid brittle failure during bending.

FIELD CUTTING OF REINFORCING BARS

An issue often occurring on construction projects is concerned with the cutting of reinforcing bars. The cutting envisioned in this discussion is unplanned cutting. It is not the kind of cutting associated with field fabrication of reinforcing bars. CRSI discourages field fabrication.

Field cutting of reinforcing bars would be required, for example, when bars are too long as a result of design changes, or when errors were made in detailing, fabrication, or placing. The field cutting could involve over-length bars prior to their placement in the forms or over-length bars that are partially embedded in hardened concrete.

Various means are used for field cutting. For smaller size bars, #10, #13 and #16, the cutting can usually be accomplished with bolt-cutters. All bar sizes can be cut with an abrasive saw, or by flame-cutting with an oxy-acetylene torch.

From CRSI's experience, questions are apt to surface regarding the suitability of flame-cutting, i.e., will flame-cutting affect the reinforcing bars? The answer is "No." The rationale: A testing program was undertaken to investigate the effect of flame-cutting reinforcing bars.

The testing program:

- Covered bar sizes #16, #25, #36 and #57.
- The test bars were Grade 420 [minimum yield strength fy = 420 MPa or 60,900 psi; Grade 420 is the metric counterpart of Grade 60].
- **The test bars were carbon-steel conforming to ASTM A615/A615M, and low-alloy steel conforming to ASTM A706/A706M.**

(* According to the CRSI Manual of Standard Practice, It is recommended that all Reinforcing bars be shop fabricated and so specified by the architect/engineer, as operations can be performed with greater accuracy in the shop.)

The results of the testing program showed that any effect of flame-cutting is localized to the end-cut surfaces. Only a very short distance or length of bar, approximately 3/16 inch, from the flame-cut ends is affected. Hardness testing was used to evaluate the effects of the flame-cutting on the tensile properties of the bars. From an analysis of the hardness test data, it was concluded that flame-cutting had no adverse effects on the bars.

Flame-cutting of epoxy-coated reinforcing bars is not recommended. Coating damage can be reduced by using other means of cutting rather than flame-cutting. After cutting epoxy-coated reinforcing bars, the cut ends should be coated with the patching material that is used for repairing damaged coating. Damaged epoxy coating in the vicinity of the cut ends should also be properly repaired.

LAP SPLICES, MECHANICAL SPLICES AND WELDED SPLICES

Lap Splices: The location and length of lap splices has always been a concern of the architect/engineer, estimator, detailer, placer, and inspector. The ACI 318 Building Code states that the design drawings shall show the location and length of lap splices. The ***ACI 315 Standard*** repeats the above requirement and further instructs the detailer to follow the architect/engineer's details, thus both the placing drawings and the structural drawings should show the same location and length of lap splices. Chapter 12 of the ***ACI 318 Building Code*** contains provisions for determining tension lap splice lengths. Lap splice lengths will vary due to concrete compressive strength, yield strength of the bars, bar spacing, epoxy coating, concrete cover, and other factors. The inspector should make certain that the specified lap splice lengths are for the strength criteria of the materials furnished to the job-site, and that the placer follows the placing drawings. Also, longer lap splice lengths are usually not detrimental.

Mechanical Splices: The ACI 318 Building Code requires the architect/engineer to show the type and location of mechanical splices on the design drawings. If a full mechanical splice is required, the inspector should make certain that a

compression-only mechanical splice is not furnished in error. In all cases, inspection should verify that the splice manufacturer's installation procedures and any instructions in the project specifications are followed. Dowel bar mechanical splices and lap-splice connector systems are used to replace pre-bent or other types of dowels which connect two separate pours of a reinforced concrete structure. The type and location should be approved by the architect/engineer.

Welded Splices: Welded splices of reinforcing bars present the same difficulty of inspection as welded structural steel connections. The ***ACI 318 Building Code (Section 3.5.2)*** states: "Type and location of welded splices and other required welding of reinforcing bars shall be indicated on the design drawings or in the project specifications." Section 3.5.2 also requires: "Welding of reinforcing bars shall conform to 'Structural Welding Code – Reinforcing Steel ***(ANSI/AWS D1.4)'*** of the American Welding Society."

It should be noted, under the AWS Welding Code, the architect/engineer is not obliged to specify the welding procedures to be used. Rather the Welding Code requires the contractor to prepare written welding procedure specifications (WPS's) for the welded splices.

Regarding inspection activities at the job-site, the inspector should review the mill test report for the reinforcing bars to determine the carbon equivalent (CE) and the preheat requirements. The inspector should be aware that both types of generally – available reinforcing bar, *ASTM A615 (Carbon-steel) and ASTM A706 (Low-alloy),* can be welded as per the *AWS D1.4 Specifications*. The difference between welding these two types is that A615 bars, depending on the CE, could require preheating up to 500°F, while A706 bars will probably not requireany preheating. Other types of reinforcing bars are available, but these are the common types in building construction.

The inspector should verify the welder's certification, confirm that the correct electrodes (oven dry) are available, and that the preheat temperature crayon sticks are at hand. Continuous inspection is usually specified to ascertain that the welder uses the proper number of passes, controls the inter-pass heat loss, and uses a wire brush and chipping hammer to remove any slag.

For some projects, the contract documents will require radiographic inspection of the welded splices. This procedure is time consuming and costly, and is frequently inconclusive. More often a test specimen located at random is removed for a laboratory tension test and analysis.

Welding of Crossing Bars: The inspector should not allow field tack welding of reinforcing bars, i.e., welding of crossing bars as means for assembly of reinforcement. Tacks welding canembrittlement the steel which reduces strength and can also have a detrimental effect on ductility and fatigue resistance. Field tack welding is not a substitute for tie wire for the assembly of reinforcing bars.

For information on shop-welded assemblies of reinforcing bars, see EDR No. 53 "Assembling Reinforcing Bars by Fusion Welding in the Fabricating Shop." Visit the CRSI Website to view and print the report.

APPENDIX A – POTENTIAL PROJECT SUBMITTAL ITEMS FOR REINFORCEMENT

(Adapted from ACI 301 – Specifications for Structural Concrete)

These items listed will be submitted by the Contractor and reviewed by the Architect/Engineer.

- Certified mill test reports on reinforcing materials.
- Placing drawings showing fabrication dimensions and locations for placement of reinforcement and supports.

- List of splices and request to use splices not indicated on the Contract Documents.
- Request to use mechanical splices not shown in the Contract Documents.
- Request for placement of column dowels without using templates.
- Request a procedure to field bend or straighten partially embedded reinforcing bars.
- Description of reinforcing bar weld locations, welding procedure specifications, and welder qualifications.
- Proposed supports for coated reinforcement and materials for fastening coated reinforcement.
- Request use of alternative reinforcement support type. When Contractor finds it necessary to move reinforcement beyond the specified placing tolerances to avoid interference with other reinforcement, conduits, or embedded items, review a submittal showing the resulting reinforcement arrangement.
- Inspection and quality-control program of plant that is not certified by Concrete Reinforcing Steel Institute.
- Provide equivalent certification program for evaluation by Architect/Engineer.
- Precast concrete support materials.
- Request to heat reinforcement before bending.
- Request to extend reinforcement through control joints, including saw-cut joints.
- Request to use an alternative method or setting column dowels.
- Request to use other method to measure preheat temperature.
- Request to field cut reinforcement.

APPENDIX B – SUGGESTED CHECKLIST ITEMS FOR REINFORCING STEEL INSPECTION

Prior to Reinforcing Bar Placement

- Obtain reinforcing bar tags and mill test reports.
- Check reinforcing bar tags for proper markings.
- Check delivered material against reinforcing bar schedules & drawings.
- Check bar markings and/or grade marks against CRSI's Manual of Standard Practice, Appendix A.
- Check reinforcing bar condition.
- Take material samples, as required.
- Check for coating damage in bundle; implement repairs before bar placement.
- Check storage of reinforcing bars. [Are all delivered reinforcing bars stored above the ground upon skids, platforms or other supports? Are epoxy-coated reinforcing bars stored on wooden or padded steel cribbing? Are the reinforcing bars protected from mechanical injury and from deterioration by exposure? For uncoated (black) bars, a light coating of rust should not be considered objectionable.]

During/after Reinforcing Bar placement

- Check reinforcing bar quantity, size, and location with plans or applicable drawings. Document as necessary.
- Check spacing before and after concrete placement.
- Check reinforcing bar concrete cover and clearances – vertical and horizontal.
- Check splice locations and splice lengths. If required, verify the lap lengths are at the minimum lengths.
- Check placement and adequacy of ties and supports. Verify tied bar junctions are adequately tied.
- Check for coating damage; patch if necessary.

- Verify bars are free of dirt, oil, rust, paint, etc.
- Are there any special trim reinforcing bars required at sleeves or openings, identified in "typical" details? (i.e., diagonal bars at corners, etc.).
- Is the reinforcement properly placed adjacent to construction joints?
- Check any reinforcement congestion concerns/problems, and evaluate prior to concrete placement.
- Where two or more separate mats of reinforcing steel are required, should each mat be independently supported by an approved support system?
- Check embedment lengths.
- Check all mechanical splices. Are the two bars entering the splice properly anchored (set screws torqued, grout installed, wedge set, etc.)?
- Hooks oriented properly?
- Headed bar anchors are installed and tight, so they will not displace during the concrete placement operation.
- Punching shear stud assemblies tied properly or attached properly to formwork?

Quality of Reinforcement Steel Bars used for Construction of RCC Structure

When a lot of steel received at site, first check the Manufacturer test certificate for its actual properties. With each lot of steel, manufacturer should send a test certificate of same lot for test done at their laboratory. Check for grade of steel mention in certificate and is as per the order or not.

Figure 1: Placement of Rebar's with Rusted Bars.

Steel bars may have rusting on it, do check closely to know either it is acceptable or not. Steel received should be free from any contamination like, mud, dust, oil and any other foreign material etc. Bars should not have splits and any other deformation on it.

Causes of Rusting

Primary steel which is made from pure iron ore are likely to get rusted quicker compare to secondary steel. Bars may get rusted due to contact with water or air and atmospheric condition.

Figure 2: Placement of Rusted Bars.

A brownish bar showing little rusting due to weathering are good for use. Small amount of rust is good for bonding of steel and concrete. If excessive scaling observed on the surface of bar, it should not be accepted.

Do check for Brand of Steel, Diameter and Grade of Steel Embossed on Steel Bars

Figure 3: Embossed or Punch logo for Rebar and dia with Grade of Steel Bars.

Cut the samples of 1 meter in length, min 4 no's of bars from different bundles. Measure the length of cut bars by measuring it on at-least 4 sides and average out the length of bar. Weight the bar on weight scale and record it in register. Calculate the actual average weight per meter of bar for at-least 3 samples.

Compare the Result of it with Theoretical weight given in IS 1786–2008

Table 3: Tolerances on Nominal Mass.

(Clauses 6.2 and 7.2.2)

Sl No.	Nominal Size mm	Tolerance on the Nominal Mass, Percent		
		Batch	Individual Sample[1]	Individual Sample for Coils Only[2]
(1)	(2)	(3)	(4)	(5)
i)	Up to and including 10	±7	–8	±8
ii)	Over 10 up to and including 16	±5	–6	±6
iii)	Over 16	±3	–4	±4

[1] For individual sample plus tolerance is not specified. A single sample taken from a batch as defined in 3.1 shall not be considered as individual sample.

[2] For coils batch tolerance is not specified.

Check the variation in weight is within limit or not as per IS specification.

After finding the results for nominal mass as satisfactory proceed further to do bend test. Bend test should be carried out as specified in **IS 1599–2017**and using mandrels of size specified in **IS 1786–2008.**

Table 4: Mandrel Diameter for Bend Test.

(Clause 9.3)

Sl No.	Nominal Size mm	Mandrel Diameter for Different Grades						
		Fe 415	Fe415D	Fe500	Fe500D	Fe550	Fe550D	Fe600
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Up to and including 20	3 ϕ	2 ϕ	4 ϕ	3 ϕ	5 ϕ	4 ϕ	5 ϕ
ii)	Over 20	4 ϕ	3 ϕ	5 ϕ	4 ϕ	6 ϕ	5 ϕ	6 ϕ

where ϕ is the nominal size of the test piece, in mm.

9.4.1 The diameter of the mandrel shall be as given below:

Sl No.	*Nominal Size of Specimen*	*Dia of Mandrel for Fe 415 and Fe 500*	*Dia of Mandrel for Fe 415D and Fe 500D*	*Dia of Mandrel for Fe550 and Fe 600*	*Dia of Mandrel for Fe 550D*
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to and including 10 mm	5 ϕ	4 ϕ	7 ϕ	6 ϕ
ii)	Over 10 mm	7 ϕ	6 ϕ	8 ϕ	7 ϕ

where ϕ is the nominal size of the test piece, in mm.

Rebar sample should be bent at 180 degree as per procedure stated in ***IS 1599–2017.*** The bend test shall be carried out in testing machines or presses equipped with the following devices:

Bending device with two supports and a mandrel as shown in Figure 1,

Bending device with a V-block and a mandrel as shown in Figure 2, and

Bending device with a clamp as shown in Figure 3.

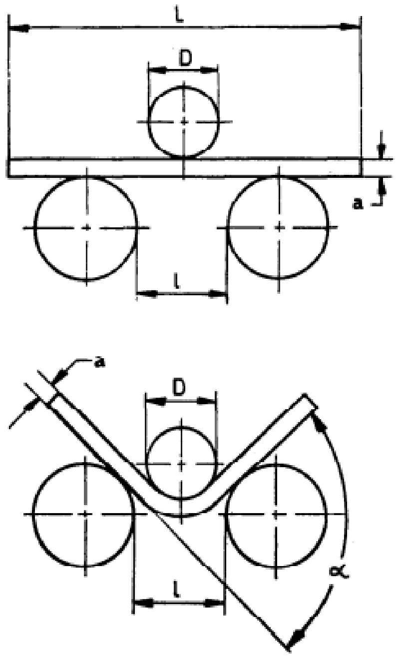


Figure 4: Simple Bend Test.

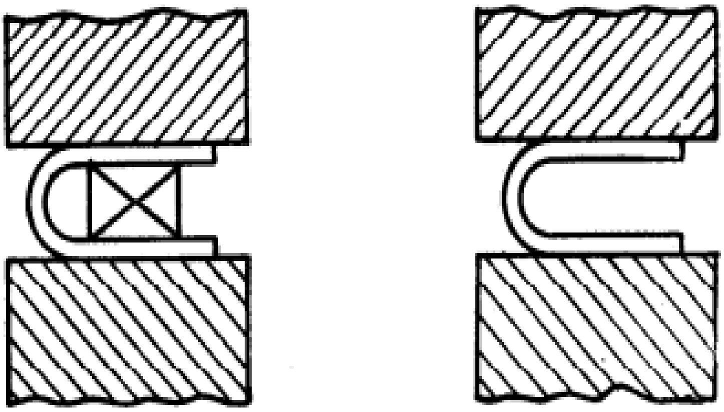


Figure 5: Bend Test Through an angle of 180° over a Specified Radius.

After this further process it is to bend till 180 degree. At site, we can bend it on bar bending machine using appropriate size mandrel. Sample tested bar.

Figure 6: Site bend Rebar Sample.

After bending the bar, check the surface of bar opposite to bend side (which got tension, elongated due to bending) for cracks and rupture visible to a person with normal or corrected vision. If there is no sign of rupture and cracks, rebar meets the requirement of bend-test.

Further to this, a re-bend test also can be done at site, if required. (IS specifies for doing but if it passes bend test, in general it will pass the re-bend test too. You can do it at side provided you have required arrangement at site for this test)

For Rebend Test

First bend the bar to include the angle of 135°. Keep it in boiling water at 100° for 30 minutes. Then cool it down for some time. After cooling bent it back to include angle of 157.5°. The rebar should not show any rupture or cracks to a person with normal or corrected vision.

Mandrel to use for Re-bend test as specified in **IS 1786–2008**

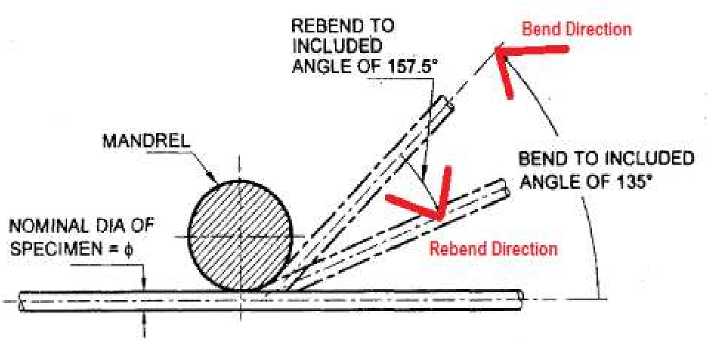
Table 5: Mandrel to use for Re-bend Test.

9.4.1 The diameter of the mandrel shall be as given below:

Sl No.	Nominal Size of Specimen	Dia of Mandrel for Fe 415 and Fe 500	Dia of Mandrel for Fe 415D and Fe 500D	Dia of Mandrel for Fe550 and Fe 600	Dia of Mandrel for Fe 550D
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to and including 10 mm	5 ϕ	4 ϕ	7 ϕ	6 ϕ
ii)	Over 10 mm	7 ϕ	6 ϕ	8 ϕ	7 ϕ

where ϕ is the nominal size of the test piece, in mm.

Below picture is showing the bend re-bend test (Closely look at the direction of bending and re-bending, in order to do correct test).



NOTE—ϕ Represents the nominal size in mm of the test piece.

Figure 7: Re-bend Test.

After getting satisfactory results, you can approve the steel for further usage in actual construction. Keep practice of getting steel tested from third party laboratory at 200 metric tons or at each lot received whichever is acceptable for your management. I personally did a bend and re-bend test for 25mm and 32 mm bar by witnessing it in third party laboratories. When steel failed at my site and got passed in multiple third party tests. When I did witness test, I shocked to see many laboratories don't have the equipment's to test it, as their current set up don't allow higher diameter bars to get bend and re-bend test. Either machine reaches its maximum capacity or there is chance of accident if we do it as per specification **(That same laboratories gave me report stating rebar failure, this is real condition at least in my area of NABL accredited labs).**

So my suggestion to all, when you get doubt on quality of steel, you personally witness the test process to understand either steel passes the test or not.

To do value Addition to Company and yourself, you can Implement following practice during unload of steel at site?

Count the amount of pubs received. Record the ordinary period of pub by performing arbitrary measurements. Calculate the true burden of steel obtained according to theoretical burden and then compare it with real complete weight. Make

comparative statement showing the version in steel weight according to manufacturer of steel. Show it into your direction that brands are providing heavy steel.

Overweight steel though it is as per tolerance provided in IS 1786 will cause a loss of money to your company, by understanding the which steel brand manufacture to optimum level and produce less overweight steel you can reduce the indirect loss to your company.

CONCLUSIONS

Each of the foregoing discussion appears to imply that the contractor has a strong mission when scrutinizing strengthening bars. This belief isn't necessarily accurate, but it's an exacting job, one which guarantees the employees do their task to the very best of their capability. All men involved with a building project, in your architect/engineer to the builder, try to do work. An excellent management program from the contractor aids in attaining this aim, making final review simpler. The inspector shouldn't perceive his function as adversarial, but as complementaryto those employees in service of great building methods and practice. Fantastic review consists of a correctly constructed arrangement; one that all parties involved with the process can take pride.

For further information on ("Case study on Field Guide for Rust on Reinforcing Bars and corrosion of steel Reinforcement: Causes, Effects and Remedies" Publish on Next incoming papers due to limitations of Papers pages").

For further information on inspection, tolerances, industry standard practices, fabricating, placing and splices, consult the following references.

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